Review and Update of the Indicator-and-Trigger Approach to Managing Discharges into Marine Receiving Environments

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Abstract
With the wide variety of management issues facing coastal jurisdictions, rational decisions have to be made about what to manage and how to manage it. Managers are faced not only with environmental responsibility, but with fiscal and societal responsibility as well. The foundation of environmental management is scientifically-based knowledge, with a reasonable temporal and spatial confidence, a long view, and the will and resources to implement it.

As part of the Liquid Waste Management Plan (LWMP), the Greater Vancouver Regional District (GVRD) has committed to a scientifically-based receiving environment monitoring program to assist in management of the two marine outfalls in the lower mainland. This work is multidirectional and includes development of sampling designs for aquatic habitats, analysis of benthic community response and recovery patterns as they relate to the environment, and statistical evaluation of observed response patterns. Fundamental to this approach is the need to rigorously quantify the magnitude and extent of biological and chemical effects of outfalls on the receiving environment. In aid of this, an extensive literature review has been conducted to assess the value and reliability of qualitative and quantitative environmental indicators, warnings and triggers recommended or in regulatory use by other marine jurisdictions and their applicability to the Georgia Basin.

Introduction
In accordance with commitments under the Greater Vancouver Regional District's (GVRD) Liquid Waste Management Plan (LWMP), the District has established a team of in-house professionals, multi-disciplinary expert consultants and partnerships with local universities and provincial and federal government agencies. The team's work is guided and reviewed by an Environmental Monitoring Committee comprised of representatives from member municipalities, the GVRD, senior governments (e.g., BC Ministry of Water, Land and Air Protection, Environment Canada and Fisheries and Oceans Canada) and the academic community (e.g., University of British Columbia and Simon Fraser University).

As part of the LWMP, the Greater Vancouver Regional District has committed to a scientifically based receiving environment research and monitoring program to provide information for the management of the two marine outfalls in the lower mainland. The basis for this extensive program is the development of a triggers and warning framework for sound environmental management of the IONA and Lions Gate outfalls. This commitment requires a series of tasks, some of which will be completed this year, some of which will be on-going parts of the environmental monitoring program. The major parts of the program are;

1. A high quality monitoring program for Iona and Lions Gate receiving environments.
2. A review of triggers, guidelines and indicators for other jurisdictions.
3. Development of appropriate triggers and indicators committed to a science-based, adaptive management approach.
4. Focused research programs to understand habitat and biotic effects of municipal wastewater.
5. Long-term ambient program: to provide the assessment and a determination of the variability of sources and fates of contaminants and other substances entering the Strait of Georgia, British Columbia.

In this presentation, we will focus on part 2, with brief reference to parts 3 and 5.

Part 2: Literature Review and Assessment
Existing guidelines and indicators for marine discharges used in other jurisdictions (primarily North America) were assessed as to their usefulness and applicability to the particular receiving water environments of the GVRD marine outfalls (Burd 2002).

Ideally, useable receiving environment guidelines should address the following questions:

1. Are contaminants getting into the system?
2. Are contaminants bio-available?
3. Is there a measurable response?
4. Are the contaminants causing this response?
5. Are the responses of ecological importance now or in the future?
6. How do we respond to ecologically important effects?

The first 4 questions are inherent in Environment Canada's national Environmental Effects Monitoring Programs (EEM) for Pulp and Paper and Metal Mining technical guidance documents (URL: www.ec.gc.ca/eem/English/PulpPaper/Guidance/default.cfm). Most of the framework and guidance that has been developed has been oriented towards answering questions 1-4. The resolution of these questions is amenable to rigorous scientific monitoring and research for receiving environments. However, questions 5 and 6 must also be addressed if triggers and warnings are to be used in a management framework for discharges such as outfalls. Questions 5 and 6 are only partially addressable by science, and partially by societal standards and ethics.

A glaring omission in most regulatory and criteria-based guidelines for environmental management is analysis of what constitutes an "ecologically significant effect." It is often not clear what the purpose is of receiving environment guidelines. Most commonly, the stated purpose of receiving environment guidelines is to "protect the health of the ecosystem." If this goal is to have a realistic function, then the parameters of a "healthy" or "unhealthy" ecosystem must be defined.

Toxicologists define ecosystem health in relation to whether or not a reasonable percentage of toxicity is possible based on controlled testing of surrogate organisms. Toxicity may be tested using whole sediments, water column samples, or test substrates "spiked" with specific compounds of interest. However, this does not address the "true" toxicity experienced by the biota in that system, or variation in toxicity amongst species and life stages. Ecologists view ecosystem "health" in relation to the overall spatial and temporal functionality and stability of the major biotic components.

In addition to preventing accumulation of toxic chemicals up the food chain, ecosystem "health" implies that a stable habitat and food supply must be maintained for the higher trophic levels. Increasingly impacted communities are characterized by progressively greater variability in abundance, biomass and biotic composition, as well as habitat conditions. This temporal variability can be a destabilizing factor in ecosystems. The spatial extent of the effects, specific location of effects relative to sensitive and important species, and temporal recovery potential are important considerations in determining ecosystem health and/or relevance of impact. However, this is difficult to measure, and endpoints are far from clear-cut. For this reason, statistical significance is generally equated to ecological significance. Thus, significant deviations from certain measured background condition are considered to be ecologically significant. Unfortunately, this approach reflects the mathematical properties of the data and sampling program, rather than the biological properties of the ecosystem. Moreover, different statistical techniques will yield different results, based on the limitations and biases of the chosen methods.

Determining ecological significance of receiving environment effects from discharges can be approached on two different scales:

A: What is the balance or stability in biotic composition and functioning of components of the receiving environment?

This implies that direct effects in the receiving environment (sessile or "captive" biota) are the focus of concern. In practice, this has been the basis for development of guidelines in most jurisdictions. The larger scale of ecological significance related to receiving environment effects does not lend itself well to focused receiving environment monitoring programs, particularly with respect to migrating or transitory populations of biota.

B: What are the ramifications of an impact up the food chain; effects on higher trophic levels up to humans (food, health and recreation)?

There may be impacts occurring outside the immediate vicinity of the discharge, which we cannot see, trace or measure. This problem has become more prevalent in recent years, as concern over known deleterious substances (such as POPs) grows. Determining these higher trophic level effects is difficult, since they may be slow to develop and difficult to trace to their origins. They are not useful for local jurisdictions because they cannot be tracked, predicted or used as management tools because of the measurement uncertainties and time scale. However, they cannot be ignored, either. Such aspects of ecological significance are best addressed through ambient monitoring programs and the careful tracking of source tracers.

Therefore, for management in real time, (A) above is the only practical way to develop triggers and guidelines for specific discharges. The indicators may be scientifically based, but the determination of what constitutes "ecological importance" is partially scientific and partially societal.

Although the importance of organic enrichment effects are recognized, and there is a vast literature going back to the early 1900s pertaining to enrichment effects on biota and habitats, the focus of jurisdictions in North America for developing receiving environment guidelines, triggers and indicators has been on chemical contaminants and their effects on receiving environments. This is problematic with respect to sewage outfalls, since the North American experience suggests that organic enrichment effects are the primary causal factors affecting receiving environments. There are geochemical effluent guidelines (e.g. BOD in effluents), but the coupling of these with observed habitat effects is largely ignored or theoretical. Some notable exceptions occur. Washington State uses sediment TOC guidelines as they relate to percent fines for Puget Sound finfish farm regulations (URL:www.leg.wa.gov/wac/index.cfm?fuseaction=chapter&chapter=173-204). The fish-farming regulatory framework for the east and west coasts of Canada include sediment "free sulphide" interim (experimental) guidelines for fish waste deposition. TOC guidelines have been found to be uninformative or poorly correlated with biotic effects in British Columbia fish farm sites (Brooks 2001) and in the receiving environment for the IONA outfall in Vancouver, B.C. (Burd 2000). Sediment free sulphide guidelines have not been attempted in relation to sewage outfalls.

Following is a tiered set of approaches used by many jurisdictions to assess receiving environment effects and regulate discharges based on monitoring programs;

Tier 1: The first step in assessing sediment or water quality conditions is the application of universal, often national or regional guidelines based on some critical mass of laboratory-based and empirical research. This approach requires no background information or understanding about the habitat in question. The review describes the historical derivation of sediment quality guidelines based on toxicity testing and equilibrium partitioning, which has been fraught with problems. More recently, measures of bio-availability and tissue level response of selected or "model" organisms to toxicants have dominated the development of guidelines. Existing national or regional sediment guidelines are generally viewed as first tier indicators, which may flag potential situations of concern and trigger further monitoring. If there is a "hit", more detailed work has to be done. However, if the guidelines are not exceeded, the decision is more difficult. Either it must be assumed that there are no receiving environment effects, or a second tier of monitoring must be done to determine if there are biotic effects.

Tier 2: The second tier of assessment is usually the "Reference Approach". Because the aforementioned "ecological" issues are tricky to assess, most regulatory agencies define ecosystem health as some proportional deviation from "normal" or "reference" conditions. The "Reference" approach implies that the habitat and/or biota in question have been examined. To set guidelines, the temporal and spatial scale of variability that can be expected in natural "present-day" conditions must be determined. This is a complex and difficult task that must be accomplished in proximity to the impact of concern. The next step is to determine on some rational basis, what deviation from "reference" is acceptable, and over what spatial and temporal scale. This is usually done statistically, but may include locally regulated initial dilution zones around the effluent source. The reference approach may be required after a first tier guideline(s) has been exceeded. However, changes from reference condition may occur without any "hits" related to guidelines, implying that something other than the "regulated" or guideline parameters is having an impact on the habitat and biota.

Tier 3: A Toxicity Identification Evaluation (TIE) may be required if an impact of concern is found in Tier 2, to determine what is causing the biotic impact. The literature on how to do this is extensive. If this approach is not suitable, an empirical "weight of evidence" assessment of the causative factor(s) may be required.

Part 3: Development of Indicators and Triggers from Receiving Environment Monitoring Programs: IONA

The data and indicators required to develop a triggers-and-warning framework for GVRD outfalls are being derived from the on-going monitoring programs at IONA and Lion's Gate. Of these, the IONA program is the most advanced. Monitoring has been conducted at IONA since before the commissioning of the deep-sea outfall in April 1988. A 10-year review was conducted (2WE 1999), resulting in a re-design of the program to focus on habitat and biotic effects along the maximum exposure gradient. The revised program has now completed 4 annual cycles from 2000 to 2003.

The revised sampling gradient was centred on the 80m depth contour to the N and S along the bank and away from the outfall. This was determined to approximate the gradient of maximum exposure, based on plume particulate deposition modelling (Hodgins and Hodgins 2000), on silver distributions in the area (Gordon 1987), and on the predominant current and sediment transport regimes. Sediment transport is from S to N along the bank and down-slope. Detailed assessment and temporal comparisons of results for the IONA monitoring program can be found in Burd (2000), EVS (2001, 2002, 2003). In summary, major results are:

1. There are no traceable water column effects or chemical contaminant elevations based on BCWQO (Fanning et al. 1997).

2. Sediment chemical contamination does not exceed CCME 1999: www.ccme.ca/publications/can_guidelines.html2000) or BCWQO (http://wlapwww.gov.bc.ca/wat/wq/BCguidelines/working.html#table2) guidelines except in the odd rare case. The exceptions are contaminants which tend to be elevated above guideline levels throughout the region, often due to geological factors (e.g. sediment copper – see Paine and Chapman 2000, EVS 2002, 2003). There are peaks in some organic compounds that have no guidelines, but seem to be related to the outfall, and in general, PAHs are dominated by Fraser River and Burrard Inlet sources (Yunker 2000). These peaks tend to be temporally unstable, and suggest episodic depositions. Biotic effects tend to be poorly correlated with contaminants levels (Burd 2000). In general, it can be concluded that there are no direct receiving environment effects evident related to the 331 measured sediment contaminants.

3. The most consistent **indicators** or tracers of outfall deposition are some sterols such as coprostanol, which have no guidelines (except CCME guidelines for nonylphenol and its ethoxylates = 1.0 mg/kg dry wt, which is orders of magnitude higher than levels found near IONA – Paine and Chapman 2000), fecal coliforms (for which there are no sediment guidelines) and AVS. These are indicators which can be specifically traced to the outfall particulate exposure (based on modelled deposition), and are unlikely to be derived from any other source. With the exception of nonylphenol, which is being addressed in a national source control program, these markers are not known to have any biotic effects, and their suitability as markers is predominantly due to their relative longevity in the sediments and their specificity to sewage effluent. These tracers allow the deposition footprint from the effluent to be defined.

4. Despite the fact that contaminants do not seem to be related to biotic effects, and the monitoring program to 2001 did not show any evidence of organic enrichment of sediments, biotic effects in sediments related to the outfall has been relatively consistent in terms of magnitude and spatial extent. For example, biotic declines in abundance and species richness, but not biomass are evident within 3 km N of the outfall and ½ km S of the outfall. Declines are most evident in the taxonomic groups considered to be sensitive indicators, in particular crustaceans and echinoderms. Enrichment of some species occurs outside this zone but within the particulate deposition area.

5. The biotic effects and indicators are consistent with a localized organic enrichment gradient related to the outfall. TOC/TON levels are low and relatively uniform in silty/sand sediments throughout the area, indicating that typical enrichment indicators may not be useful in an area with high inorganic loading from freshwater discharges. Having determined with a reasonable certainty that sediment geochemical changes related to organic enrichment are affecting biota in the IONA region, it remains to be determined the ecological importance and regional context of these effects (the answers to question 5 above; are the responses of ecological importance now or in the future?).

Part 5. Ambient Monitoring Program

In order to put the effects of sewage outfalls into context with respect to the multiple sources of discharges and factors potentially affecting the Strait habitats, the GVRD initiated an Ambient Monitoring Program to develop budgets and assess sources and sinks of organic and inorganic inputs and contaminants into the Strait of Georgia. In addition, the program will track cyclical or climate-related patterns in biotic factors to help differentiate between natural and anthropogenic effects.

GVRD currently has a 5-year Collaborative Agreement with the Canadian Department of Fisheries and Oceans and Natural Resources Canada to undertake a multi-disciplinary research project which involves water column and sediment research related to sources, sinks, burial, transport of organic and inorganic particulates, DOC, DIC, PAHs and metallic contaminants. In addition, the research incorporates long-term monitoring of biotic assemblages, to assess climate effects, unusual recruitment or mortality issues, etc. DFO and NRCan are interested in regional management issues, and understanding the scales and sources of problems which need targeting in the heavily industrialized southern Georgia Strait. GVRD is interested in maintaining a context for the contribution to contaminants and biotic effects from the sewage outfalls and ultimately other discharges in the regional district. This information will help in the process of reviewing, refining and verifying the utility of the indicators, warnings and triggers developed for the marine outfalls. For this reason, indicators, warnings and triggers developed for the GVRD marine outfalls will, of necessity, be considered to be interim triggers, subject to continuous testing and verification over time. This approach recognizes the fact that scientific knowledge is in continuous development. Thus, the selected indicators, warnings and triggers must be adaptive to allow for improved scientific understanding and methodology. The GVRD/DFO/NRCan ambient program is designed to assist in the development of this knowledge, and is therefore an integral part of the GVRD's environmental management strategy.

The Trigger Framework

The development of indicators, warnings and triggers for the GVRD requires judgements about ecological importance and context for the environment. The context requires spatial and temporal boundaries. Where habitat and biotic effects of the outfalls are clear, indicators and warnings can be readily developed based on changes in the exposure zone relative to ambient or reference levels. However, development of triggers which can have major management, source control and infrastructure consequences requires more rigorous decisions about the ecological importance of the observed effects and projections of future trends.

The answers to question 6 above; how do we respond to ecologically important effects? will determine how a trigger framework is devised. Triggers imply that some response to specific conditions or changes in conditions in the receiving environment must be standardized. In order to do this, it must be determined what goals or end-results are desired. In other words, how should the public and the GVRD balance:

- Enrichment versus impoverishment effects.
- Fisheries enhancement and related environmental effects.
- Importance of patch size of effects to the general bio-diversity and temporal stability of the Strait of Georgia.

This is the task that will be the focus of work on this project for the coming year, and into the future.

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References Cited

2WE Consulting 1999. Iona deep-sea outfall 1998 environmental monitoring program, post-discharge review, Report for Greater Vancouver Regional District by 2WE Associates Consulting Ltd., Victoria, B.C.

Brooks, K.M. 2001. An evaluation of the relationship between salmon farm biomass, organic inputs to sediments, physiochemical changes associated with those inputs and the infaunal response-with emphasis on total sediment sulfides, total volatile solids, and oxidation reduction potential as surrogate endpoints for biological monitoring. Consultant Report, Technical Advisory Group, Ministry of Environment, Lands, and Parks, Port Townsend, Washington.

Burd, B.J. 2000. Ecological effects and indicators analysis for the IONA receiving environment. *In* Development of a receiving environment monitoring approach to liquid waste management: Progress workshop 2. *Edited by* GVRD. Burnaby, B.C. December 6, 2000. GVRD, pp. Chapter 5 - 48 pp.

Burd, B.J. 2002. Ecological Quality and Assessment Program: Greater Vancouver Regional District: Review of marine biotic, chemical and physical triggers, warning levels and indicators used in other jurisdictions. Report to the Greater Vancouver Regional District. December, 2000.

EVS Consultants 2001. IONA Deep Sea Outfall. 2000 Environmental Monitoring Program. Final Report, Prepared for the Greater Vancouver Regional District, Burnaby, BC.

EVS Consultants Ltd. 2002. IONA deep sea outfall. 2001 Environmental Monitoring Program, Draft Report, Prepared for the Greater Vancouver Regional District, Burnaby, BC.

EVS Consultants Ltd. 2003. *In preparation:* IONA Deep Sea Outfall 2002 Environmental Monitoring Program, Draft Report, Prepared for the Greater Vancouver Regional District, Burnaby, BC.

Fanning, M. L., N. J. Rising, D. W. Larson, M. J. Stewart, and S. E. Bertold. June 1997. *Iona Deep Sea Outfall, 1996 Environmental Monitoring Program, Receiving Water Quality.* Prepared for Greater Vancouver Regional District by IRC Integrated Resource Consultants Inc., Richmond, BC, and Quality Control Division, GVRD, Burnaby, BC, 105 pp. + Appendices.

Gordon, K. 1997. Sedimentary tracers of sewage inputs to the southern Strait of Georgia. M.Sc., University of British Columbia, Vancouver, BC.

Paine, M.D., and Chapman, P.M. 2000. Assessment of sediment chemistry in the IONA receiving environment. *In* Development of a receiving environment monitoring approach to liquid waste management: Progress Workshop 2. Vancouver, B.C. December 6, 2000. GVRD, pp. Ch. 2 2-1 to 2-73.

Yunker, M.B. 2000. Sediment PAH signatures in the IONA receiving environment. *In* Development of a receiving environment monitoring approach to liquid waste management: Progress Workshop 2. *Edited by* GVRD. Burnaby, B.C. December 6, 2000. GVRD, pp. Chapter 3- 23 pp.